Space Technology Research Grants

2D Materials for Energy Harvesting and Sensing

Completed Technology Project (2017 - 2021)

Project Introduction

This project proposes collaboration between the Massachusetts Institute of Technology and NASA to design and fabricate a self-powered sensor using two dimensional (2D) materials including Tungsten Diselenide (WSe2), Molybdenum Disulfide (MoS2), and graphene. In particular it will focus on the optimization of a 2D material energy harvester and chemical sensor to demonstrate a specific system for which 2D materials have unique advantages over their competitors and immediate benefits in their application. Self-powered sensing systems can be incorporated into embedded systems that monitor the structural integrity of spacecraft, sample the chemistry of a foreign environment, or keep track of an astronaut's health through smart textiles. To accomplish such a goal, this project will focus on studying the material characteristics of chemical vapor deposition (CVD) grown 2D materials and from this point develop devices that can harvest energy from their environment and power a semiconducting sensing component. This project will be divided into five areas of development: (1) I will need to develop a standard, clean and repeatable process for working with transferred CVD material. I will especially need to investigate device passivation layers needed to achieve optimal device performance. My colleagues have done extensive work on this for MoS2, however I would need to extend this knowledge in working with CVD grown WSe2. Work in this portion of the project will involve short loop processes and extensive characterization. (2) The second task will be to develop computational models of my CVD grown materials to better predict changes in the materials' band structure and resultant transport properties due to material alterations such as strain, passivation, and chemical doping. Once I begin testing fabricated devices, I will also develop upon compact models that my colleagues have developed for MoS2 transistors to better understand how my devices will behave in a circuit. I will collaborate with another lab that specializes in density functional theory to develop the previously mentioned materials models. (3) In parallel to task 2 and using the results from task 1, I will begin experimental work to develop chemical sensors. These sensors will be designed to optimize their stability, sensitivity, response time, and selectivity. (4) The fourth task will be to work on an energy harvesting device. The goal here is to aim for both open circuit voltage and high short circuit current to supply useable power to a load circuit. My first focus will be on photovoltaics, as 2D materials, in particular WSe2, show unique promise in this area to create thin, flexible, high efficiency and stable solar cells. I will also look into the possibility of generating power through chemical gradients as this is a viable alternative energy source for circuits exposed to wet or highly acidic/basic environments. (5) The final culminating task will be to integrate the energy harvesting component with the chemical sensor. This portion of the project will aim to demonstrate the applicability and value of 2D materials as the foundation of a distributed sensing network circuit block. It will require technology and expertise developed from the previous four steps. This project brings together Electrical and Materials Engineering disciplines to probe the capabilities of 2D materials

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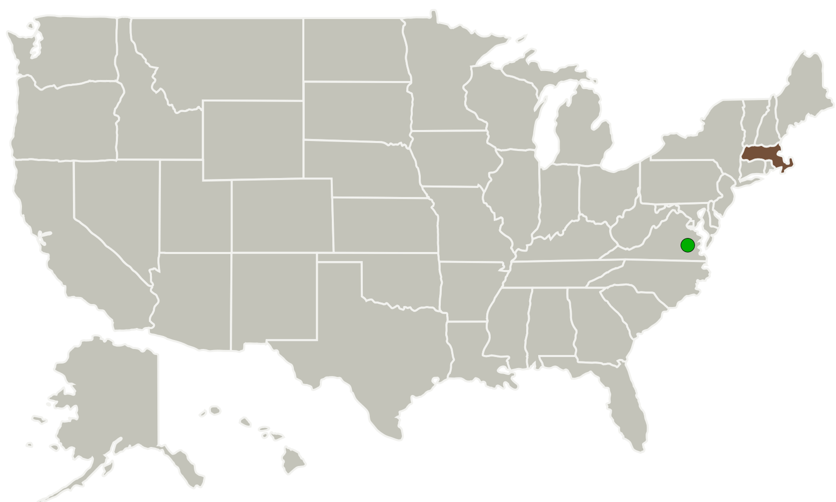
to harvest energy and collect data. Success in this project will enhance our knowledge of the characteristics of and methodology needed to develop a self-powered system, and finally give us the potential to develop custom ubiquitous electrical systems that can aid all avenues of space exploration that require sensing capabilities. In the future, distributed sensor networks based on this technology could be discretely incorporated into everyday objects, making them "smart" to enhance users' interactions with their environment.

Anticipated Benefits

Self-powered sensing systems can be incorporated into embedded systems that monitor the structural integrity of spacecraft, sample the chemistry of a foreign environment, or keep track of an astronaut's health through smart textiles. Success in this project will enhance our knowledge of the characteristics of and methodology needed to develop a self-powered system, and finally give us the potential to develop custom ubiquitous electrical systems that can aid all avenues of space exploration that require sensing capabilities. In the future, distributed sensor networks based on this technology could be discretely incorporated into everyday objects, making them "smart" to enhance users' interactions with their environment.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Massachusetts Institute of Technology (MIT)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Tomas Palacios

Co-Investigator:

Elaine D Mcvay

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Organizations Performing Work	Role	Type	Location
Massachusetts Institute of Technology(MIT)	Lead Organization	Academia	Cambridge, Massachusetts
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia

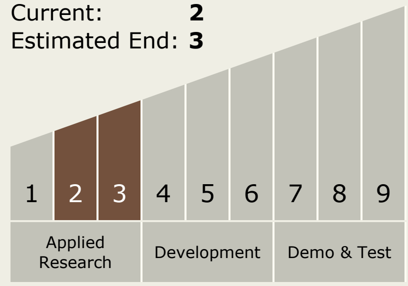
Primary U.S. Work Locations
Massachusetts

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  - └ TX12.1 Materials
    - └ TX12.1.6 Materials for Electrical Power Generation, Energy Storage, Power Distribution and Electrical Machines

Target Destinations

Earth, The Moon, Mars